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Factors affecting mandibular residual ridge resorption in edentulous patients: a preliminary report

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The aim of the study was to assess the rate of mandibular residual ridge resorption in edentulous patients and to analyse the factors which determine this process. A group of 35 edentulous patients aged between 51 and 89 years, with a mean age of 74 (65–78) years, were included in the study. Individual factors (age, gender and duration of edentulousness), local biochemical parameters (oral hygiene and history of periodontal diseases) and systemic biochemical parameters (calcium and phosphate metabolism, diet, smoking, alcohol intake and systemic diseases), as well as physical factors involved in the process (the use of prosthetic dentures), were analysed. The study was performed on the basis of the results of dental examinations, assessment of panoramic radiograms, research surveys and total calcium and phosphate serum levels, which were determined using a calorimetric method. Bone resorption in the mandible affected all the study patients to varying extents. More than half the edentulous patients showed a high degree of mandibular residual ridge resorption. The duration of mandibular edentulism was found to be closely associated with values of the radiological IC/IM index, which is generally considered to reflect the degree of mandibular resorption. Total calcium serum levels were shown to correlate positively with the value of IC/IM index in these patients.

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Key words: residual ridge resorption, mandible, edentulousness

INTRODUCTION

In a prosthetic sense, bone is considered to be the base which provides support for dentures. In the physiological sense, it is an area where forces created while biting and chewing foods are transmitted. In the course of life continuous bone rebuilding occurs. In young and healthy individuals the process involves a relative balance between bone resorption and absorption, with the result that premature bone loss is not observed. In older people the life span and proliferation of osteoclasts is significantly decreased, which results in domination of the resorptive processes over osteogenesis. Bone loss is considered to commence in humans at 35–40 years of age, after peak bone mass has been achieved, and the atrophic processes then continue with varying intensity, accelerating in perimenopausal women as compared to men [17, 26].

An increased bone rebuilding intensity is also observed in areas where pressure is exerted on the alveolar surface. In humans with natural dentition forces created during occlusion of the maxilla and the mandible are transformed through the teeth and peridontium onto the lamina dura and the adjacent

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trabeculae. Particularly problematic is non-physiological pressure, which is created while transforming masticatory forces through dentures, their plate and the mucous membrane on the periosteum and the bone. The thickness and elasticity of the mucosa become, to a great extent, pressure regulators in this case [23].

In research conducted by numerous authors a difference between the rate of mandibular alveolar resorption and resorption of the maxillary alveolar process has been reported. According to Atwood, the degree of mandibular loss of its alveolar portion is three or four times higher than alveolar resorption in the maxilla, which is due to a smaller denture-bearing area in the mandible and thus a greater load per square cm [1]. Differences in resorption can have effects which are limited to the alveolar process in the maxilla, rarely moving to its body, while in the mandible changes also affect the mandibular angle, leading to its atrophy. Alveolar loss in the maxilla runs from the cheek to the palate in the horizontal plane, in the mandible the alveolar ridge becomes atrophic in the glosso-bucal direction in its lateral parts, while in the anterior part this occurs from the oral vestibule [13].

According to Parkinson [16], an increase in the incidence of mandibular as opposed to maxillary resorption is more rapid in the initial edentulous period and decelerates as bone loss progresses.

The phenomenon of mandibular residual ridge resorption in edentulous patients is currently considered a serious clinical issue. Progressive bone loss without proper prosthetic treatment and rehabilitation of the masticatory organ can contribute to numerous unfavourable consequences. Toothlessness results in mastication impairment as well as loss of parodontal tissue receptors, which play a significant regulatory role in the function of the masticatory organ. The efficiency of mastication is thus markedly decreased. Apart from this, it can alter the nutrition habits of the elderly in favour of a high-fat diet, avoidance of fibre, raw vegetables and fruit. As a result, a deterioration in general condition and an increased risk of cardiovascular and neoplastic disease can occur [24].

In order to avoid the potentially severe sequelae of mandibular residual ridge resorption in edentulous patients and to provide proper protection to a degree dependent on dentists, knowledge of the causative factors which affect alveolar resorption in the mandible is necessary. The process is determined by numerous factors [1]. The speed and extent of resorption are individual features. However, a few basic reasons for this process can be noted, such as ontogenetic factors (age and sex), osteoblast life span, time elapsed since tooth extraction, local and systemic biochemical factors and physical factors, such as the pressure exerted on the bone by dentures [23].

The aim of the study was to assess the rate of mandibular residual ridge resorption in edentulous patients and to analyse the factors which can determine that process.

MATERIAL AND METHODS

The study group consisted of 35 randomly selected patients treated in the Department of Dental Prosthetics, Institute of Dentistry, Medical University, Łódź (F/M = 22/13) with recognised mandibular edentulism who used dentures. The ages of the patients studied ranged from 51 to 89 years, with a median age of 74 (65–78) years.

The study was performed on the basis of a research survey of the conditions affecting alveolar resorption in the mandible, physical examination and analysis of panoramic radiograms. Calcium and phosphate metabolism was assessed: serum total calcium and serum phosphate levels were determined using the colorimetric method. Parameters studied in the research surveys included the following: age, gender, duration of edentulism, smoking, alcohol intake, diet, hygiene regimens concerning the mouth and dentures used, duration of the use of the prosthetic denture and its replacement and the patient's history of periodontal and internal diseases.

The physical assessment included an intra-oral examination. On the basis of radiological analysis of the pantomograms (as described by Wical and Swoope, modified by Ortman) a resorption index (IC/IM) was calculated, where IC is the distance between the inferior ridge of body of the mandible and the ridge of the alveolar part adjacent to the mental foramen and IM is the distance between the lower ridge of the mandible body and the inferior margin of the mental foramen (Fig. 1). Classes of mandibular residual ridge resorption were established on the basis of IC/IM index value. Results for IC/IM index > 2.34 were classified as mild resorption (class I), those ranging between 1.67 and 2.33 were defined as a moderate grade of resorption (class II) and values for IC/IM index < 1.66 were considered to represent a severe grade of resorption (class III). The IC/IM index was similarly used to assess the percentage of bone mass atrophy in each patient.

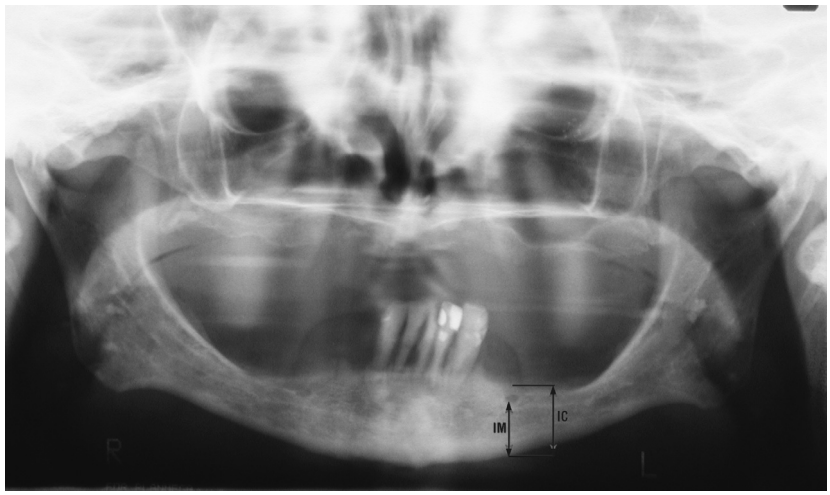

Figure 1. Resorption index (IC/IM) as described by Wical and Swoope, modified by Ortman.

Table 1. The incidence of particular classes of mandibular alveolar resorption in edentulous patients

Grade of resorption	Right side of the mandible	Left side of the mandible	p
Mild (class I)	2/35 (5.7%)	2/35 (5.7%)	
Moderate (class II)	11/35 (31.4%)	13/35 (37.1%)	0.87
Severe (class III)	22/35 (62.9%)	20/35 (57.2%)	

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Statistical analysis

The normality of the variance distribution was verified using the Kolmogorov-Smirnov test. Student's t test and the χ^2 test were applied to compare the values for the radiological indices on the right and left sides of the mandible. The χ^2 test and the Kruskall-Wallis test for a three-column distribution were used to analyse the effect of the particular parameters on the degree of mandibular residual ridge resorption. Analysis of IC/IM index values with respect to the parameters studied was performed using Spearman's correlations.

Values of $p < 0.05$ were considered statistically significant.

RESULTS

On the basis of the preliminary results of the present study, which was performed in a group of 35 patients with mandibular edentulism, right- and left-sided alveolar resorption in the mandible was found all the subjects. The mean value of IC/IM index derived from pantomogram analysis amounted to 1.64 ± 0.36 on the right side and 1.61 ± 0.32 on the left side ($p = 0.8$) of the mandible.

A severe grade of resorption (class III) was predominant both on the right and left side of the mandible. The incidence of particular classes of alveolar resorption on both sides of the mandible in study group as a whole is presented in Table 1. The percentage (%) of bone loss in the mandible in the whole study group was also determined on the basis of the IC/IM index value. This amounted to 45.25 ± 12.1% on the right side and 46.14 ± 10.7% on the left ($p = 0.75$).

Analysis of the effect of patient age on residual ridge resorption failed to show any differences in the incidence of the particular classes of resorption measured as a value of IC/IM index, either for the right side of the mandible ($p = 0.6$) or the left ($p = 0.8$).

Class III resorption, the severe grade of atrophy, occurred most frequently in this study, both in patients over and in those under 74 years of age. Nor were any statistically significant sex-related differences observed in the incidence of any particular degree of right-sided ($p = 0.9$) or left-sided ($p = 0.1$) mandibular residual ridge resorption.

However, a negative correlation was noted between the duration of edentulousness and IC/IM index value for the right side of the mandible

Table 2. Correlations between duration of edentulousness and radiological indices of mandibular alveolar resorption

	Right side of the mandible	Left side of the mandible
Duration of edentulousness *vs*. IC/IM	r = –0.33; p < 0.05	p = 0.08 (NS)
Duration of edentulousness *vs*. % of resorption	r = 0.33; p < 0.05	p = 0.09 (NS)

(r = –0.33, p < 0.05). No such correlation was found for the left side (p = 0.08). Duration of edentulousness also correlated with the percentage index of right-sided mandibular residual ridge resorption (Table 2).

Analysis of the effects of local biochemical factors on alveolar resorption in the mandible included assessment of the hygienic status of the oral cavity and the patient's history of periodontal disease. No significant differences were found in the occurrence of particular classes of right- and left-sided resorption in relation to oral hygiene, classified as satisfactory or poor (p = 0.9 and p = 0.5, respectively) or history of periodontal disease, classified as positive or negative (p = 0.9 and p = 0.3, respectively).

As regards systemic biochemical parameters, diet was not shown to influence the incidence of the particular classes of right- and left-sided alveolar resorption in the study group of patients (p = 0.8 and p = 0.8). Similarly, no statistically significant differences were found in the incidence of consecutive grades of right- (p = 0.6) and left-sided (p = 0.08) alveolar resorption with respect to certain systemic diseases, particularly osteoporosis and disease of the thyroid gland.

Analysis of calcium and phosphate metabolism revealed differences in total calcium serum concentrations in the patients studied, depending on the degree of alveolar resorption (Fig. 2). The highest calcium levels were found in patients with mild (class I) left-sided alveolar resorption (9.2 ± 0.2 mg/dl) compared to moderate (class II) alveolar resorption (9.1 ± ± 0.6 mg/dl) and severe (class III) alveolar resorption, for which the calcium serum level was 8.6 ± 0.6 mg/dl (p < 0.05).

A positive correlation was found between calcium serum concentration and the value of IC/IM index for the left side (r = 0.33, p < 0.05). No such relationship was noted for phosphate serum concentration (Fig. 3).

No differences were shown in the incidence of particular grades of right- or left-sided alveolar resorption in relation to the effect of smoking (p = 0.7 and p = 0.07) and alcohol intake (p = 0.1 and p = 0.1, respectively) either.

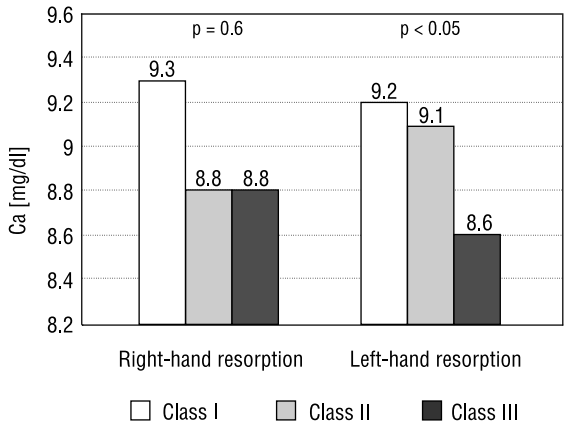

Figure 2. Total calcium serum concentration (Ca) in edentulous patients and grade of right- and left-sided mandibular residual ridge resorption.

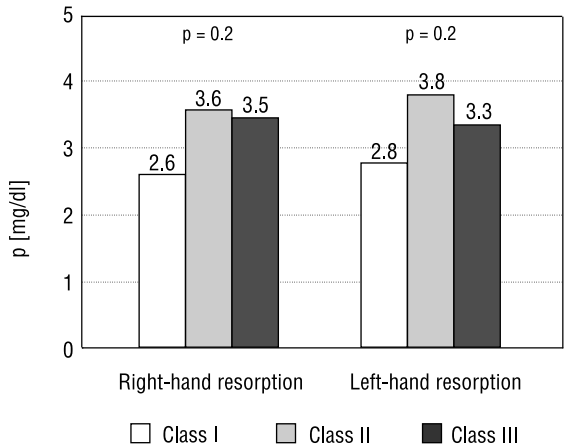

Figure 3. Phosphate serum concentration (p) in edentulous patients and grade of right- and left-sided mandibular residual ridge resorption.

Analysis of the effects of physical factors on mandibular bone resorption included the duration of denture use. However, no correlation was observed between values of IC/IM index for the right (p = 0.6) or left side (p = 0.5) and the length of denture use.

DISCUSSION

Mandibular residual ridge resorption in edentulous patients was evaluated in this study. The process

was observed in 100% of the study subjects, its course being similar on the right and left sides of the mandible. Most frequently found was a severe grade of alveolar resorption, found in 60% of patients. According to Von Wowern [25], the incidence of mandibular residual ridge resorption in edentulous patients above 70 years of age varies with gender and amounts to 1.5% in females and 0.9% in males. In the clinical and radiological studies performed by Siedlecki et al. [21] severe bone loss and residual ridge resorption was found in 61% of edentulous patients and mainly involved the mandible. Similar results were obtained as a result of radiological analysis of the masticatory organ in edentulous patients who were treated by Markiewicz et al. [14] and Rusiniak-Kubik et al. [18].

Of the determinants of mandibular alveolar resorption, individual factors, local and systemic biochemical parameters and physical factors were discussed in this study. No association was found between the age or gender of patients and the grade of mandibular alveolar resorption. Atwood and Coy [2] also pointed out the absence of any close association between a patient's age and the intensity of mandibular alveolar resorption. Slightly different results were reported by Rusiniak-Kubik et al. [19], indicating an increase in mandibular residual ridge resorption in the course of the life of an edentulous patient and double the incidence of severe atrophy in females as compared with males. A correlation with sex was also shown by Kordatzis et al. [10] and Solar et al. [22], who revealed that female gender was an independent risk factor for more severe bone resorption. However, in the study by Atwood and Coy [2] mandibular alveolar resorption was shown to have a loose association with gender.

According to numerous authors, the duration of edentulousness is one of the most important factors contributing to the severity of mandibular bone loss [3, 9]. It is considered that alveolar ridge resorption progresses most rapidly during the first six months and lasts for two years following tooth extraction, although it may continue throughout life in some patients, thus leading to the destruction of the bone structure of the alveolar process [13, 23]. In the study by Karaagacliou and Ozkan [8] bone resorption progressed more rapidly in the initial period of edentulousness and slowed down with time. Parkinson [16] also found a decreasing rate of mandibular bone resorption in the course of edentulousness and showed a relationship between the duration of toothlessness and the grade of resorption intensity. In the present study the duration of edentulism was found to affect the degree of mandibular bone loss. The length of this period negatively correlated with the value of the radiological IC/IM index as a marker of mandibular bone resorption.

Of the local biochemical factors which determine bone loss in edentulous patients attention should be paid to endotoxins from dental plaque formed on the dentures. This process is augmented by bad oral hygiene, especially during the 24-hour use of dentures. It has been demonstrated that bone loss is strongly correlated with dental plaque accumulation [23]. The results of the present study do not confirm this correlation. No direct relationship was found between mandibular residual ridge resorption and oral hygiene, denture care or history of periodontal disease.

Of the systemic biochemical factors which affect mandibular bone resorption, disorders of calcium/phosphate metabolism and hormonal disturbances head the list. Of all the systemic factors associated with mandibular bone loss in edentulous patients osteoporosis is considered the most important. Edentulism and osteoporosis are common pathogenic processes in the elderly. They appear independently but their common feature is bone resorption, occurring as a chronic and irreversible process. Studies conducted by Gołębiewska et al. [5] in edentulous postmenopausal women have revealed significant alveolar resorption in all the groups examined. The most severe loss of the cortical bone of the mandible was observed in females with osteoporosis. In this group the highest percentage of severe resorption of mandibular cortical bone was found. Osteoporosis significantly affected residual ridge loss of the edentulous mandible in the women examined. Similar results were observed by Czajkowska et al. [4], a more severe grade of bone base destruction being found in those patients with osteoporosis than in those without it; these authors considered clinical features of the masticatory organ to be a criterion for the early detection of osteoporosis. Concomitant endocrine disorders also contribute to alveolar mandibular resorption in edentulous patients. Hyperparathyroidism, hyperthyroidism and oestrogen deficiency are considered the most harmful disorders in this process. A correlation between parathyroid hormone levels and bone mass loss and residual mandibular resorption was observed and reported by Lekkas [12]. Using an animal model, Nishimura et al. [15] demonstrated the effect of systemic oestrogen deficiency on alveolar resorption. The mechanism of this

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phenomenon was confirmed in further experimental studies, which revealed that oestrogens induce apoptosis of osteoclasts [7]. It is conceivable that oestrogen deficiency can prolong the life span of osteoclasts and, at the same time, contribute to more intense bone resorption in postmenopausal women.

No correlation between osteoporosis or endocrine disorders and grade of bone resorption was found in the present study. However, it seems that this may be due to the relatively small study group and the resulting small number of patients with established osteoporosis and diseases of the thyroid gland.

Appropriate diet and abstention from smoking and excessive alcohol intake are also significant factors in maintaining the good condition of the bones, including the bone mass of the mandible. In the present study no correlation between these factors and the grade of mandibular bone resorption was found. It seems, however, that although a single factor had no particular influence, there is a cumulative effect when they are taken together.

A diet rich in calcium and phosphorus, with proper proportions between these two elements and supplementation with vitamin D3, is of great significance for inhibiting bone resorption. It has been confirmed in an animal model using a scanning electron microscope that alveolar bone resorption associated with features of demineralisation occurs in rats with calcium deficiency [5]. The beneficial effect of oral administration of calcium and vitamin D3 on mandibular bone mass in postmenopausal women was confirmed by the results of a study by Kribbs, who assessed the two-year use of 1000 mg of calcium and 400 IU of vitamin D3 daily. In 83% of women mandibular bone mass was not diminished despite the passage of two years, and an increase was even observed [11]. The results of the present study confirm the association between total serum calcium level and grade of mandibular residual ridge resorption.

Physical factors are the last parameter considered and evaluated in the present study. In particular, the role of denture use in the mechanism of residual ridge resorption in edentulous patients is discussed. The use of complete dentures can have a particularly disadvantageous effect on the masticatory organ [3]. It seems that overly good adherence of dentures to the denture bearing area can lead to augmented bone atrophy [23]. According to Majewski [13], an even distribution of masticatory forces via the denture base and a proper course of the occlusion surface are essential in the prophylaxis of residual ridge resorption.

Studies carried out using an animal model have shown the threshold value of pressure in the induction of bone resorption for a continuous or intermittent type of pressure. The continuous pressure threshold accounts for 20–40% of the intermittent pressure value, which demonstrates that exerting continuous pressure is more harmful than intermittent pressure [2]. Thus it seems possible to determine the borderline threshold value at which bone resorption would not occur [6]. The 24-hour use of dentures has a particularly bad influence on the residual ridge. In the present study the length of denture use was assessed as a possible factor for mandibular bone mass loss in edentulous patients. No relation was found between these parameters however, probably because of the relatively small size of the group.

CONCLUSIONS

1. It was observed that mandibular residual ridge resorption affected all the edentulous patients in the study group to varying extents.
2. More than half the edentulous patients showed a severe (class III) grade of intensity of mandibular residual ridge resorption.
3. It was found that the duration of mandibular edentulism was associated with the value of the radiological IC/IM index, which defines the grade of mandibular residual ridge resorption and the percentage mandibular bone loss in edentulous patients.
4. The total calcium serum level was shown to correlate positively with the value of IC/IM index in edentulous patients.

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